2019 Sessions

Singh, R., Corle, E., Jain, R., Kim, J., "Computation and Quantification of Uncertainty in Predictions of HVAB Rotor Performance in Hover," AIAA 2019-0285, AIAA SciTech 57th Aerospace Sciences Meeting, 7-11 January 2019, San Diego, CA.

> The HVAB rotor hover performance predictions are obtained using coupled aero-structural modeling. A computational structural dynamics (CSD) model based on the US Army Rotorcraft Comprehensive Analysis System (RCAS) is used. The aerodynamic modeling employs two levels of fidelity, 1) a mid-fidelity finite-state, dynamic inflow model available in RCAS itself, and 2) a high-fidelity strand grid-based CFD modeling available in CREATE™ Helios. Rigid and elastic rotor performance predictions are obtained for both mid- and high-fidelity modeling, and are compared against each other and the previously published results. Rotor elasticity effects are further studied by conducting rotor performance sensitivity analysis to the blade structural properties. For this purpose, an automated Uncertainty Quantification (UQ) analyses process is developed through integration of RCAS in the DAKOTA framework. The process is demonstrated by computing the rotor performance response distribution to a prescribed distribution of blade structural properties. Analyses showed that the process is capable of evaluating effects of model parameters on computational predictions and provides additional information that is not available using traditional sensitivity analyses

Lee, B., Jung, Y.S., Jude, D., Baeder, J.D., "Turbulent Transition Prediction of PSP Hovering Rotor Using γ-Reθt-SA with Crossflow Transition Model," AIAA 2019-0286, AIAA SciTech 57th Aerospace Sciences Meeting, 7-11 January 2019, San Diego, CA.

> Turbulent transition of Pressure Sensitive Paint (PSP) hovering rotor was simulated using a compressible Reynolds-averaged Navier–Stokes (RANS) solver OVERTURNS. The hybrid RANS-LES SA-DDES model was applied as a baseline turbulence model and $\gamma - Re_{\theta t} -$ SA with crossflow transition model was employed to predict laminar-turbulent transition. Simulations were performed for the isolated PSP Rotor at a tip Mach number of 0.58 and collective pitch angles of 6°, 8°, and 10°. Predicted Figure of Merit and transition locations were compared against the experimental data and other numerical results. Radial loadings of thrust and torque were compared between transition and fully turbulent simulations. In general, predicted rotor performance and transition locations were in good correlations with the experimental data, but Figure of Merit was underpredicted at collective pitch of 10°.

Fitzgibbon, T., Barakos, G.N., Woodgate, M.A., Jimenz-Garcia, A., "Numerical Simulations of Various Rotor Designs in Hover and Forward Flight," AIAA 2019-0287, AIAA SciTech 57th Aerospace Sciences Meeting, 7-11 January 2019, San Diego, CA.

> This paper presents numerical simulations of different rotor designs using high-fidelity CFD methods. Firstly, hover results are presented for the PSP rotor blade. The impact of a transitional turbulence model on the blade performance was examined and good correlation with test data was obtained. A grid sensitivity study indicated an influence on the transition location predictions, however, the effect on the integrated loads was not significant. The surface pressure distributions and sectional loads were also examined. The PSP rotor was also simulated in forward flight and blade surface pressure was compared with wind tunnel data. The predictions were found to follow data obtained from pressure transducers.

Carnes, J.A., Coder, J.G., "Computational Assessment of the HVAB Rotor in Hover Using Laminar-Turbulent Transition Modeling," AIAA 2019-0288, AIAA SciTech 57th Aerospace Sciences Meeting, 7-11 January 2019, San Diego, CA.

Hover predictions of the Hover Validation and Acoustic Baseline (HVAB) rotor are made using a computational fluid dynamics approach. Solutions are generated using the NASA OVERFLOW 2.2n solver with both hybrid RANS/LES and laminar-turbulent transition modeling enabled. Solutions are based on a hover tip Mach number of 0.675 for a pre-deformed rotor with prescribed collective pitch, lag, and coning angles. Grid generation and computational methods are described. The rotor flowfield is analyzed and the effect of the transition model is assessed through comparison to predictions made using a fully-turbulent modeling approach.

Zhou, C., Sankar, L.N., Griffin, P., "Effects of Anhedral on S-76 Hover Aerodynamics," AIAA 2019-0289, AIAA SciTech 57th Aerospace Sciences Meeting, 7-11 January 2019, San Diego, CA.

A systematic study of the effects of tip shape on hover performance of a baseline S-76 rotor has been conducted by a number of researchers worldwide. Rectangular planforms, and swept-tapered planforms with and without anhedral have been systematically studied. The simulations and the test data all indicate that rotors with an anhedral tip achieve the best performance in hover. In this work, the underlying physical mechanisms behind this improvement are explored. For a given thrust level, the figure of merit does improve as the anhedral angle is progressively increased. Our results indicate that rotors with anhedral tips experience a slightly greater radial contraction of the tip vortices, causing the tip vortices from the preceding blades to move farther inboard compared to other planforms. Our results also indicate that anhedral tip vortices are somewhat weaker, and more diffused. This was traceable to a smoother radial variation of the blade loading near the tip. Finally, rotors with anhedral tips had a more uniform inflow at the rotor disk. Additional parametric studies are in progress.

Abras, J.N., Narducci, R., Hariharan, N., "Wake Breakdown of High-fidelity Simulations of a Rotor in Hover," AIAA 2019-0593, AIAA SciTech 57th Aerospace Sciences Meeting, 7-11 January 2019, San Diego, CA.

Complete wake breakdown is a well-documented phenomenon associated with computational fluid dynamic hover predictions. As the computational state-of-the-art for hover predictions has progressed, allowing for higher resolution of the rotor wake, this phenomenon has become more severe; thus, resolving this open question has become more important to increase understanding of how and why it occurs and define a path forward. The present work investigates the wake breakdown phenomena using the S-76 isolated rotor. This investigation includes a discussion of physical flow features that are felt to influence both physical and computational wake breakdown as well as an analysis of the computational inputs that can influence these flow features. This includes an analysis of relative vortex core position and strength as a function of wake breakdown and a parameter study to look at off-body grid structure. The grid study employs both cylindrical and Cartesian grids and different grid densities to investigate how these settings influence physical flow features and the initiation of wake breakdown. Rotating and stationary grids are also included in this study. As a result of these studies clear impacts to the wake breakdown have been discovered.

Zhao, Q., Baugher, S., Sheng, C., "NASA PSP Rotor Hover Simulation with Fuselage Effect," AIAA 2019-0594, AIAA SciTech 57th Aerospace Sciences Meeting, 7-11 January 2019, San Diego, CA.

The hover performance and flow field for the NASA Pressure Sensitive Paint rotor are investigated using an unstructured grid Computational Fluid Dynamics solver U2NCLE. The Langtry-Menter local correction-based transition model, integrated into both the Spalart-Allmaras and the Shear Stress Transport turbulence models, is used to investigate the transition phenomena on the PSP rotor. The effects of grid resolution, turbulence model and fuselage interaction are assessed, and computational results are compared with the recent experimental data taken from the NASA Langley Research Center.

Hwang, J.Y., Kwon, O.J., "Numerical Study of PSP Rotor Blades using a γ-Reθt-CF+ Turbulent Transition Model," AIAA 2019-0595, AIAA SciTech 57th Aerospace Sciences Meeting, 7-11 January 2019, San Diego, CA.

In the present study, numerical simulations of the PSP rotor in hover are conducted by using a Reynolds-averaged Navier-Stokes CFD flow solver based on unstructured meshes. The calculations are made of a collective pitch angle from 4 to 12 degrees with an interval of 2 degrees at two blade tip Mach numbers of 0.585 and 0.65. The improved $\gamma\text{-}Re_{\theta t}\text{-}CF+$ model is adopted for predicting laminar-turbulent onset phenomena involving crossflow induced transition. To further investigate the effects of the $\gamma\text{-}Re_{\theta t}\text{-}CF+$ transition model, flow simulations are also carried out using the baseline $\gamma\text{-}Re_{\theta t}$ model and the $k\omega\text{-}SST$ fully turbulent model. The predicted results such as transition onset locations and rotor aerodynamic performances in terms of thrust coefficient, torque coefficient and figure of merit are compared with experimental data. The change of transition onset position depending on the blade tip Mach number of 0.585 and 0.65 is also investigated.

Quackenbush, T.R., Whitehouse, G.R., "Analysis of Rotor/Airframe Interaction in Hover and Near-Hover Flight Conditions," AIAA 2019-0596, AIAA SciTech 57th Aerospace Sciences Meeting, 7-11 January 2019, San Diego, CA.

For physically realistic rotor systems, integrated performance in hover and near-hover (low speed or low wind) conditions depends critically on rotor/airframe interaction, specifically the complementary issues of airframe download and thrust recovery. This paper summarizes the most recent developments in an ongoing study of these issues as well as the supplementary validation of physics-based prediction methods recently used to analyze this problem. The focus is on application of two contemporary "mid-fidelity" analysis tools chosen for their suitability for use in preliminary and conceptual design, assessing their modeling of the impact of airframe interaction on rotor performance and extending previous download predictions from pure hover to near-hover conditions. Correlation studies presented include prediction of near-hover performance of full size rotors as well as hover download and airframe/rotor interaction for sub-scale systems. The models used, a comprehensive rotorcraft analysis and a cutcell octree Cartesian CFD method, have to date produced encouraging results when applied to problems relevant to the study of advanced tiltrotor and compound rotorcraft configurations. The levels of setup and computational effort required make them consistent with use in early stage design, though significant limitations and development needs remain.

Pérez, A., Lopez, O., Poroseva, S., Escobar, J.A., "Free-Vortex Wake and CFD Simulation of a Small Rotor for a Quadcopter at Hover," AIAA 2019-0597, AIAA SciTech 57th Aerospace Sciences Meeting, 7-11 January 2019, San Diego, CA.

Performance of small rotors is a subject of interest due to increased use of Unmanned Aerial Vehicles (UAVs). In the present paper, numerical simulations of a small rotor commonly used in quadcopters were performed in hover flight. Computational Fluid Dynamics (CFD) and Unsteady Vortex Lattice Method (UVLM) were used and compared. CFD simulations were conducted with the commercial software Fluent ANSYS v17 using the Multiple Reference Frame (MRF) model. In UVLM, a model based on a viscosity dependent growth of the core of the tip vortex was used to account for viscous effects. The wake structure, pressure coefficient distribution on the rotor surface, thrust and torque coefficients obtained by different methods are compared in the paper. Results from flight tests are used to validate thrust and torque predictions. The difference in the prediction of the thrust coefficient between the computational methods is less than 9%. Both methods overestimate the thrust by 3% and 12% for CFD and UVLM respectively with respect to the flight test results.